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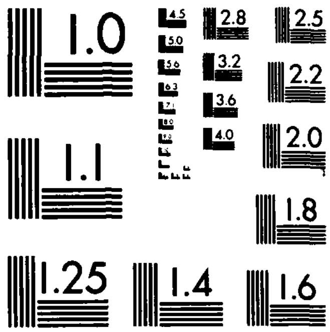

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The Hydrologic
Engineering Center

THE HYDROLOGIC ENGINEERING CENTER'S ACTIVITIES IN WATERSHED MODELING

by Gary W. Brunner

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THE HYDROLOGIC ENGINEERING CENTER'S

ACTIVITIES IN

WATERSHED MODELING

By

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I. INTRODUCTION

The Hydrologic Engineering Center has been active in watershed modeling since it was founded in 1964. Originally several small computer programs were written to model individual parts of the rainfall-runoff process. In 1968 the first Flood Hydrograph Package was put together by combining the individual watershed simulation components into one computer program. This program was called the "HEC-1 Flood Hydrograph Package" since it was the first package simulation program developed by the HEC.

The main purpose of the HEC-1 Flood Hydrograph Package is to simulate rainfall-runoff processes during a single flood event. The development of the model has evolved, for the most part, through the needs of the Corps field offices. Other government agencies, as well as the private sector, have also provided valuable feedback that has contributed to the capabilities of the current HEC-1 model.

II. REVIEW OF CURRENT MODELING PROCEDURES IN HEC-1

The vast acceptance of the HEC-1 model is due to its wide range of hydrologic capabilities, unique analysis features and user support. The following paragraphs describe the modeling capabilities of the current HEC-1 Flood Hydrograph Package.

A. User Environment

This section discusses how the user interfaces with the current HEC-1 model. Specifically, three areas are discussed: (1) Data Input; (2) Model Execution; and (3) Output.

1. Data Input

Input to the model is currently accomplished by creating an input data file before executing the program. The data file can be created through the use of any text editor. The structure and format of the input is explained in a comprehensive user's manual that is provided with the software (HEC-1, Flood Hydrograph Package, User's Manual, January 1985). The user's manual provides a detailed description of each data record and explains how these records are used to describe a particular watershed and flood event.

2. Model Execution

Execution of the model is done in a batch mode. In this mode of operation the input and output files are specified on the command line or in a batch file. Upon execution the program takes control and does not interface with the user until the entire job is completed.

3. Output

The model generates an output file which can be displayed on the screen or sent to a printer for a hard copy. The output file can contain input data feedback, intermediate simulation results, summary results, printer plots of hydrographs, and possible error messages. The degree of detail of the program output file can be controlled by the user.

B. Hydrologic Analysis

The following two subsections describe the current hydrologic analysis features contained in HEC-1. The first subsection describes the routines that make up the core of the model, which are hydraulics and hydrology related. The second subsection will focus on the supporting analysis features that have been built around the core routines.

1. Hydraulics and Hydrology

The heart and soul of any watershed model are the hydraulics and hydrology routines that are incorporated into the core of the model. HEC-1 has several options available for modeling each portion of the hydrologic process. The following is a description of the main routines available in HEC-1.

Precipitation: Historical as well as hypothetical rainfall events can be simulated with the HEC-1 model. The following is a list of the different ways that a precipitation hyetograph can be generated:

* Basin Average Precipitation
* Weighted Precipitation Gages
* Synthetic Storms From Depth-Duration Data
* Standard Project Storm
* Snowfall and Snowmelt

Historical rainfall events can be simulated with either one of the first two choices. The user can directly enter basin average precipitation that has been computed external to the model. Otherwise, measurements from several rain gages can be entered and the program can be used to compute a weighted average precipitation depth and temporal distribution. A triangular synthetic hyetograph can be generated by entering depth-duration data from publications such as TP-40 (National Weather Service, 1961) and HYDRO-35 (National Weather Service, 1977). This synthetic method can be used to generate events of different return periods and for durations ranging from 5 minutes to 10 days. There is an option to generate a Corps Standard Project Storm (SPS) for basins of area 10 to 1000 square miles located east of 105° longitude. The SPS is determined by specifying an index precipitation, a storm reduction coefficient, and the area over which the storm occurs. Where snowfall and snowmelt are considered, there is a provision for separate computation of this process by either a simple degree-day or more complex energy-budget method.

Interception/Infiltration: The present infiltration methods contained in HEC-1 are primarily designed for single event analysis. The four options available in the HEC-1 model are the following:

* Initial and Uniform Loss Rate
* Holtan Loss Rate
* SCS Curve Number
* HEC Exponential Loss Rate

Any of the four methods can be used to calculate basin average losses during a subbasin runoff computation. Two things should be noted about the precipitation loss computations. First, any precipitation that does not contribute to runoff

is considered to be lost from the system. Second, out of the four loss rate functions, only the Holtan method provides for any soil moisture recovery.

Transformation of Rainfall excess to Runoff: The HEC-1 program calculates surface runoff by convoluting rainfall excess through a unit hydrograph or by the kinematic wave transformation. The following options are available in the HEC-1 model:

* Clark Unit Hydrograph
* Snyder Unit Hydrograph
* SCS Unit Hydrograph
* Input Known Unit Graph
* Kinematic Wave Transformation

Channel Routing: Channel routing is accomplished through any one of five different methods provided in the model. The following routing options are available in the HEC-1 program.

* Modified Puls
* Normal Depth
* Muskingum
* Kinematic Wave
* Average Lag Methods

In all of these methods, routing is accomplished on a reach by reach basis. The program starts upstream and works its way down stream to the outlet. Backwater effects and discontinuities in the water surface are not taken into account during the routing.

Reservoir Routing and Dam-Break Analysis: Routing flow through a dam is accomplished with the level-pool reservoir routing technique. Reservoir storage data can be entered directly or the program can be used to calculate it based on area versus elevation data. Reservoir outflow relationships can be entered directly as a rating curve, or the program can be used to calculate storage-outflow relationships from a description of the outlet works (Low-level outlet and spillway). The program is also capable of calculating flows overtopping the dam as well as flows through a dam breach.

Pump and Diversion Capabilities: The HEC-1 model has the capability of simulating pumping operations at a reservoir or detention and ponding areas. Multiple pumps may be used, each with different on and off elevations and flow rates. The program also has the capability to divert flow from any point in the watershed. Diversions are accomplished by entering tables of inflow versus diverted flow at the desired location. Diversion and pump flows may be retrieved at any point downstream of the diversion or pump operation.

2. Supporting Analysis Features

Encompassing the main hydraulics and hydrology routines are several supporting analysis features. These features were put into the program to aid the user when performing a hydrologic analysis. The following is a description of the main analysis features.

Parameter Optimization: The HEC-1 model has the capability to automatically calibrate certain data parameters. This can be accomplished for a single subbasin where gaged precipitation and runoff records are available. The model compares computed and observed hydrographs by calculating an objective function equal to the square root of the weighted squared difference between computed and observed hydrograph ordinates. Presumably, the optimal parameter estimates are obtained when the objective function is at a global minimum. The model is capable of optimizing on the following parameters:

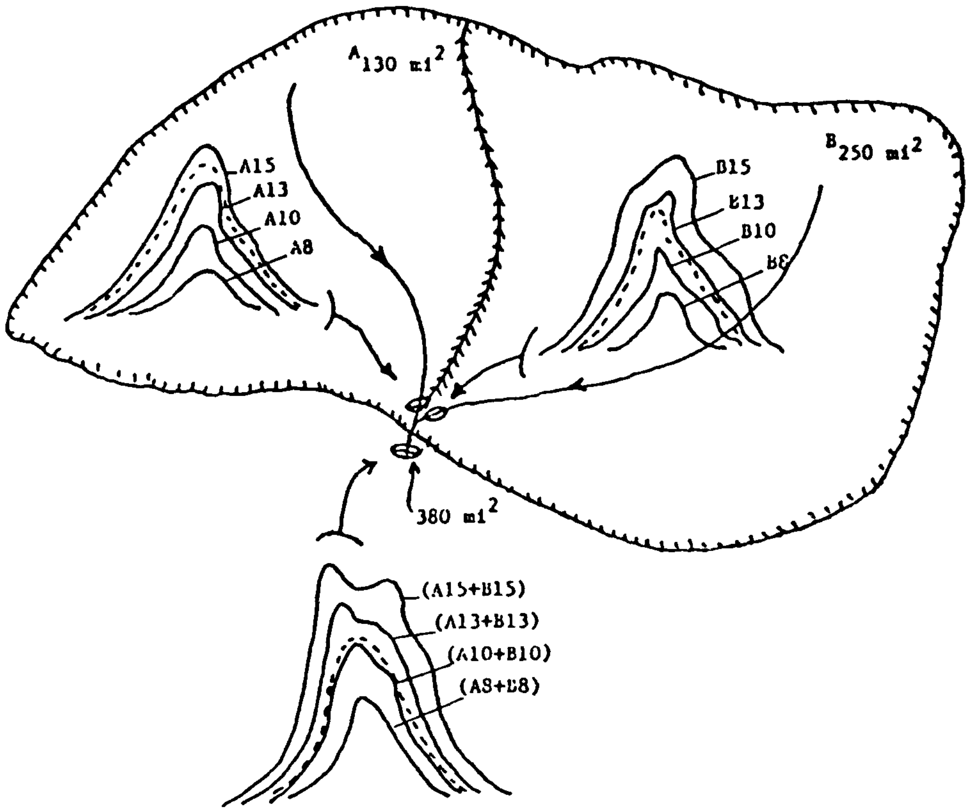
* Unit Hydrograph Parameters
* Loss Rate Parameters
* Baseflow Parameters
* Channel Routing Parameters

The optimization of channel routing parameters can only be performed for a single reach where the upstream and downstream flows are known.

Multiplan - Multiflood Analysis: The multiplan - multiflood analysis features allow the user to incorporate several different characterizations (plans) of a watershed within one model, and also analyze a series of floods for each plan. This powerful analysis feature allows up to forty five (45) different simulations within one execution of the program. The multiplan analysis feature allows the user to conveniently specify several different flood control measures and changes in runoff response characteristics at any location in the watershed. The multiflood option allows the user to evaluate a series of floods by either taking ratios of precipitation or by directly looking at ratios of runoff hydrographs. In the case of rainfall, ratios of the event hyetograph are taken and a runoff simulation is done for each ratio. In the case of runoff, the rainfall-runoff event is simulated and ratios of hydrograph ordinates are taken for each subarea runoff calculation in the model.

Precipitation Depth-Area Option: The average depth of precipitation for a specific frequency event (e.g. 1% or 100 yr) generally decreases with an increase in contributing area. Therefore, if a specific return period event were to be calculated at several locations in a watershed, multiple storm centering and magnitudes would have to be evaluated. The Depth-Area option allows for a consistent calculation of floods with the same return period at all locations in the watershed. To accomplish this, the user is requested to enter a range of precipitation depth versus drainage area values that would encompass all possible contributing area amounts in the watershed. Rainfall runoff calculations are simulated at all locations in the watershed for each precipitation value entered on the depth-area table. The resulting hydrographs are termed "Index Floods." At each control point in the watershed the actual contributing area is known. Given this value of contributing area, the correct runoff hydrograph is interpolated from the Index flood hydrographs. This process maintains consistency since the interpolated hydrograph corresponds to the appropriate precipitation depth for that specific amount of contributing area. This process is demonstrated graphically in Figure 1.

Flood Damage Analysis: The HEC-1 model has the capability of computing Expected Annual Damage (EAD) for any location in a river basin. Alternative projects can be simulated and their corresponding values of EAD can be calculated to evaluate the economic value of each flood control plan. Flood control benefits are calculated as the difference between with and without project flood damages.



Precipitation Depth-Drainage Area Function

Area - mi^2	Precip - In.
100	15
200	13
500	10
1000	8

Legend

- Desired location for consistent hydrograph
- Stream channel
- Drainage boundary
- $^A130$ mi^2 etc. - Subarea label and drainage area

Figure 1. Two-Subbasin Precipitation Depth-Area Simulation

The required input to the model consists of a flow (or stage) - frequency relationship, flow (or stage) - damage relationship, and possibly a stage-discharge rating curve. One of each of these relationships is required for each damage reach that is to be evaluated.

Data Storage System (HECDSS): The HEC Data Storage System (HEC, 1985) was originally developed to allow the transfer of data between HEC programs. HEC-1 has the capability of writing and reading several types of data to and from HECDSS. These data types consist of flow, precipitation, storage, and stage. HECDSS has several utility programs for manipulating and presenting data. These utility programs enable editing of data, purging or inserting data sets, as well as graphical and tabular portrayal of data.

C. Limitations of HEC's Current Watershed Model

Every computer model works under certain constraints and limitations. The following is a list of limitations in the current HEC-1 model that are under consideration for improvement in HEC's future watershed model:

1. The present version of HEC-1 executes in a batch mode, where the user does not have the capability to interface with the program during execution.

2. The program is geared towards single event analysis and does not have the capability to do continuous simulation.

3. Only a single computational time interval may be specified for all hydrologic calculations.

4. Entering data is accomplished by creating an input data file before execution. The creation of this data file is not done on an interactive basis, and therefore lacks user friendliness.

5. Channel routing is accomplished by hydrologic methods on a reach by reach basis. Storage effects are not considered dynamically, and downstream backwater problems are not considered during an upstream routing computation.

6. Reservoir analyses are geared towards uncontrolled structures and do not allow for releases based on downstream flow conditions.

7. Graphics and summary tables are limited to line printer output.

III. NEAR-TERM DEVELOPMENTS FOR HEC-1

Recently the HEC has been working on several enhancements to the current HEC-1 model. Many of these enhancements have already been completed, while others are currently being worked on. The following paragraphs describe the near term developments for HEC-1.

A. User Environment

The way software interfaces with the user has vastly changed in the past few years. The term "User Friendly" is now a household word for software

developers. The engineering world is no exception to this transition. Several mainframe computer programs have been converted to run on microcomputers, and user friendliness has become a major concern in this transition. The next three sections will discuss w' at the HEC has been doing to make HEC-1 user friendly.

1. Data Input

Getting data into the model in a convenient manner has been a major concern of the HEC. To aid the user in preparing input data, the following enhancements are underway. First, a full screen data editor called COED (HEC, February 1987) has been developed and is included in the HEC-1 package. Not only does COED have several advanced editing features, but is also has several capabilities that aid in generating input files specifically for HEC programs. These capabilities include:

* Automatic tab settings for each data input line.
* Automatic justification of data in each field.
* Display of the correct variables for each field of the current input record.
* Checking for non-numeric data at the time of entry.
* Online definitions of data input variables.

Second, a user friendly data input program is under development for new and intermediate users. The program is designed to lead the user into selecting the correct sequence of data input records for their specific HEC-1 application. COED can then be used to identify the specific data requirement of each record. This program is still in the early stages of development, but is scheduled for a preliminary version to be completed in the near future.

2. Model Execution

The major advancement in model execution has been the development of a menu system that drives the program on a PC. This menu system (MENU1) is also included in the new HEC-1 package on the PC. As shown in Figure 2, the MENU1 program has five main capabilities.

* <u>Define input/output files</u>: This option is used to define the target input and output filenames that will be passed to the HEC-1 program, as well as all other utilities executed from this menu.

* <u>Create/edit input file</u>: This option invokes the full screen editor, COED, and passes the input filename that is to be worked on.

* <u>Run HEC1</u>: This option executes the HEC1 program and passes the input and output filenames to be used during execution.

* <u>Display output to the console</u>: This option is used to view output on the screen or to send it to the printer.

* <u>Exit to DOS</u>: This option simply returns control back to DOS.

HEC1 Package Menu

1. Define input/output files

2. Create/edit input file

3. Run HEC1

4. Display output to console

5. Exit to DOS

INPUT: (specify)	OUTPUT: CON

Press number of desired option or ↑ ↓ with <ENTER>

January 1987 version

FIGURE 2. HEC-1 Package Menu

3. Output

To help the user view the output more conveniently, two utility programs have been included in the HEC-1 package. Both of these utilities can be executed through option 4 in the MENU1 program. Displaying output on the screen is done with a utility called LIST. LIST has several nice features for displaying output, including the capability to view output greater than 80 characters wide. Sending output to the printer is accomplished with a utility program called PROUT. The PROUT utility ensures that the carriage control information is recognized by the printer.

Graphics capabilities are presently not available directly with HEC-1. Though in the near future graphics capabilities will be possible via HECDSS. HECDSS has a utility program called DSPLAY that is capable of plotting time series data, such as precipitation, flow, stage, and storage. Currently this capability only exists on Corps of Engineers Harris computer systems. A microcomputer version of HECDSS will be available to the general public in the near future.

B. Hydrologic Analysis

The next three sub-sections will be used to describe current developments in the area of hydrologic analysis. The first two sub-sections will specifically be about developments in HEC-1. The third sub-section will pertain to the work that the HEC has been doing in the area of Real-Time Water Control.

1. Hydraulics and Hydrology

In general there have not been a lot of changes to the hydraulics and hydrology routines in HEC-1. For the most part minor modifications have been made and a few new routines have been added. The only major modification to the program was the addition of a submergence algorithm in the dam-break routines. This algorithm is used to evaluate tailwater conditions and the effect of tailwater on the breach hydrograph.

2. Supporting Analysis Features

Several new analysis features have been added to the HEC-1 model recently. These analysis features include the following:

* Single event flood damage can now be calculated through HEC-1. Previously, this computation was limited to the calculation of Expected Annual Damage (EAD).

* Capabilities for writing Stage-Frequency curves to DSS have been added.

* Time series data in DSS can now be stored at standard time intervals and beginning dates that might be different than the computational interval and starting time specified on the HEC-1 IT record.

* The latest version of the program has been converted to Fortran 77 (ANSI Standard). This conversion was done to ensure that the program can be transported to several different computer systems.

3. Real-Time Flood Forecasting (HEC-1F)

During the last several years the HEC has been involved in developing and adapting software for real-time data acquisition, analysis, short-term runoff forecasting, reservoir system analysis, and graphical display of data and simulation results (Pabst and Peters, 1983). The runoff forecasting portion of this system is accomplished through a special version of HEC-1 called HEC-1F (Peters and Ely, 1985). The HEC Flood Forecasting system operates in the following manner:

* The acquisition of real-time data is accomplished by the deployment of Data Collection Platforms (DCP) at several key locations within a watershed.

* The data are transmitted on a real-time basis to Corps computer facilities and is converted to the desired engineering units. Simple range checks on data validity are performed. Isolated periods of missing data are filled in by interpolation methods.

* Based on data availability, a time of forecast is adopted.

* Spatial averaging of precipitation data is performed on a real-time basis. The software is capable of handling changes in the gaged network do to missing data from any gage.

* Automatic estimation of runoff parameters (unit hydrograph, loss rate and baseflow) for gaged headwater subbasins is performed.

* Based on the results of parameter estimation, loss rate and baseflow parameters are adopted for remaining subbasins.

* Runoff hydrographs are calculated, routing and combining is performed and calculated hydrographs are blended to agree with observed hydrographs wherever observed data are available.

* Runoff hydrographs are used with a reservoir system simulation model to make reservoir release decisions.

* Results are analyzed using graphical displays. Additional analyses are performed with alternative future - precipitation assumptions and/or operation policies as desired.

The HEC Flood Forecasting System is made up of several computer programs that accomplish the tasks stated previously. To facilitate the use of all the components that are executed during a forecast, an interactive computer program called MODCON was developed. MODCON acts as the interface between the user and the water control software during a forecast.

Near-term enhancements to the HEC-1F model will include the implementation of a continuous soil moisture accounting algorithm. The soil moisture

accounting routines are expected to aid in the analysis of complex events. Along with the soil moisture accounting routines, new parameter optimization techniques to aid in the calibration of model parameters will be added.

IV. FUTURE DEVELOPMENTS FOR HEC-1

The remaining portion of this paper will be devoted to discussing the HEC's plans for a future watershed model. The following paragraphs focus on the direction that HEC is taking in the areas of user environment and hydrologic analysis.

A. User Environment

The HEC's next-generation watershed model will be designed primarily to function within a workstation environment. This workstation environment will be micro-computer based, while still maintaining capabilities to function on a mini or mainframe computer. The work station will emphasize data and results analysis through graphic displays. The model will be a modular program with the core routines strictly limited to precipitation-runoff analysis, channel routing, and simulation of natural and man-made structures. Separate modules will provided for executing program options, preparing input, viewing results, printing reports, and managing data. The following three sub-sections discuss future modes of data input, model execution, and output.

1. Data Input

Input modules will include both interactive and non-interactive modes for entering data. The interactive mode will lead the user through the input preparation, assuring that the appropriate data and parameters are available for the analysis. "Expert Systems" are being developed to provide additional hydrologic modeling expertise to the user. The non-interactive model would allow an experienced user to efficiently enter data by making option selections from a menu-driven system. Both modes of input preparation will have editing capabilities. Also, expert systems theory will be used to check for data errors and bounds limitations. Online help will be available for input guidance, and a printed user's manual will contain detailed information as a reference guide.

2. Model Execution

Model execution will be performed in a batch or interactive mode from a menu-driven system. In the batch mode all input is provided for the entire analysis prior to initiation of the computation. The program is executed completely prior to examination of the results (this is the manner in which HEC-1 presently operates). In the interactive mode, input is provided incrementally, computations are performed incrementally, and results are viewed incrementally. For example, in a catchment with an upstream and downstream subdivision, parameters are provided for the upstream subcatchment, the runoff is computed, and the output is viewed prior to analysis of the downstream catchment. The same approach can also be used for sensitivity analysis with a completed model. The interactive approach essentially puts the user inside the model so that the impacts of changes in the model can be rapidly known. Thus if parameters are to be adjusted, this is accomplished in a rapid and meaningful manner.

3. Output

Output from the model will be available in several forms. First, the current mode of generating an output file will be retained. Second, the user will be able to control the amount of output as well as the format. Capabilities for generating report quality tables and summary output will be provided. Third, graphics routines will be available for displaying and analyzing the results on the screen, sending displays to the printer, or creating quality pen plots. CAD-type systems may be used to enhance the graphic representation of the hydrologic processes. Finally, extensive error messages will be provided to guide the user in correcting problems that arise due to bad input.

B. Hydrologic Analysis

Several new routines will be added to provide state-of-the-art analysis in addition to most of the existing capabilities. The following is a discussion of what new routines are proposed for HEC's future watershed model.

1. Hydraulics and Hydrology

In the area of hydraulics and hydrology the following new routines are proposed for the future model:

* The addition of a simple soil moisture accounting routine that will make use of data that is readily available. As mentioned previously, this is currently being implemented in the HEC-1F model.

* The inclusion of the Green-Ampt method as another alternative precipitation-loss function. The USDA is working on relating the parameters of this model to measurable catchment characteristics.

* Addition of a diffusion routing routine, like the Muskingum-Cunge method, as an alternative to the current flood routing methods. Longer river reaches (where unsteady flow hydraulics are required) will automatically be linked together and the HEC-1 watershed runoff treated as local inflow. This may also be accomplished through storage of the inflow and local flows in the HECDSS for subsequent automatic retrieval by an unsteady flow model like DWOPER (NWS, 1978).

* Additional capabilities for reservoir analysis, which will include the ability to specify release schedules.

* Inclusion of a variable computation time step. This time step will be picked by the program based on the physical data and solution technique being used for that particular computation.

2. Supporting Analysis Features

In addition to new hydraulics and hydrology routines, several new analysis features will be added to the future model.

* In general, soil moisture accounting routines have more parameters to calibrate than traditional loss rate functions. Due to the large number of calibration parameters, the current optimization technique in HEC-1 will not be adequate. Therefore, new optimization techniques will be implemented for calibration purposes.

* In order to gain better estimates of spatially averaged data, remote sensing information will be used where it is applicable. Specifically, any information that can aid in the estimates of spatially averaged rainfall would be a great advancement. The HEC hopes to accomplish this by making use of radar techniques, such as the National Weather Services NEXRAD (Next Generation of Radar) system. The structure of the watershed model will be modified to better accept/represent these spatially varying processes.

* The use of digital terrain methodologies will be incorporated to aid in the calculation of model parameters and to better represent the spatial variability of hydrologic processes. Digital terrain and geographic information systems (GIS) approaches allow for automatic watershed subdivision; calculation of overland flow parameters; development of unit hydrograph parameters and stream routing coefficients.

V. SUMMARY

The current methodologies of the HEC-1 Flood Hydrograph Package were presented. The HEC-1 model provides a wide range of hydrologic capabilities along with several unique analysis features. The current limitations of the model were reviewed. Presently, much work is being done to overcome several of these limitations. Near-term developments have concentrated on making the operational environment user friendly and improving several of the hydrologic analysis features. The direction of HEC's future watershed modeling efforts was described. These efforts focus on improving the user environment and advancing the hydrologic analysis capabilities to maintain state-of-the-art technology.

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TECHNICAL PAPERS (TP)

Technical papers are written by the staff of the HEC, sometimes in collaboration with persons from other organizations, for presentation at various conferences, meetings, seminars and other professional gatherings.

This listing includes publications starting in 1978.

HEC NUMBER	TITLE	HEC PRICE	NTIS NUMBER
		$2.00 Each	
TP-52	Potential Use of Digital Computer Ground Water Models, D. L. Gundlach, Apr 78, 38 pp.		AD-A106 251
TP-53	Development of Generalized Free Surface Flow Models Using Finite Element Techniques, D. M. Gee and R. C. MacArthur, Jul 78, 21 pp.		AD-A106 252
TP-54	Adjustment of Peak Discharge Rates for Urbanization, D. L. Gundlach, Sep 78, 7 pp.		AD-A106 253
TP-55	The Development and Servicing of Spatial Data Management Techniques in the Corps of Engineers, R. P. Webb and D. W. Davis, Jul 78, 26 pp.		AD-A106 254
TP-56	Experiences of the Hydrologic Engineering Center in Maintaining Widely Used Hydrologic and Water Resource Computer Models, B. S. Eichert, Nov 78, 16 pp.		AD-A106 255
TP-57	Flood Damage Assessments Using Spatial Data Management Techniques, D. W. Davis and R. P. Webb, May 78, 27 pp.		AD-A106 256
TP-58	A Model for Evaluating Runoff-Quality in Metropolitan Master Planning, L. A. Roesner, H. M. Nichandros, R. P. Shubinski, A. D. Feldman, J. W. Abbott, and A. O. Friedland, Apr 74, 81 pp.		AD-A106 257

HEC NUMBER	TITLE	HEC PRICE	NTIS NUMBER
		$2.00 Each	
TP-59	Testing of Several Runoff Models on an Urban Watershed, J. Abbott, Oct 78, 53 pp.		AD-A106 258
TP-60	Operational Simulation of a Reservoir System with Pumped Storage, G. F. McMahon, V. R. Bonner and B. S. Eichert, Feb 79, 32 pp.		AD-A106 259
TP-61	Technical Factors in Small Hydropower Planning, D. W. Davis, Feb 79, 35 pp.		AD-A109 757
TP-62	Flood Hydrograph and Peak Flow Frequency Analysis, A. D. Feldman, Mar 79 21 pp.		AD-A109 758
TP-63	HEC Contribution to Reservoir System Operation, B. S. Eichert and V. R. Bonner, Aug 79, 28 pp.		AD-A109 759
TP-64	Determining Peak-Discharge Frequencies in an Urbanizing Watershed: A Case Study, S. F. Daly and J. C. Peters, Jul 79, 15 pp.		AD-A109 760
TP-65	Feasibility Analysis in Small Hydropower Planning, D. W. Davis and B. W. Smith, Aug 79, 20 pp.		AD-A109 761
TP-66	Reservoir Storage Determination by Computer Simulation of Flood Control and Conservation Systems, B. S. Eichert, Oct 79, 10 pp.		AD-A109 762
TP-67	Hydrologic Land Use Classification Using LANDSAT, R. J. Cermak, A. D. Feldman and R. P. Webb, Oct 79, 26 pp.		AD-A109 763
TP-68	Interactive Nonstructural Flood-Control Plannng, D. T. Ford, Jun 80, 12 pp.		AD-A109 764

TECHNICAL PAPERS (TP)(Continued)

HEC NUMBER	TITLE	HEC PRICE	NTIS NUMBER
		$2.00 Each	
TP-69	Critical Water Surface by Minimum Specific Energy Using the Parabolic Method, B. S. Eichert, 1981, 15 pp.		AD-A951 599
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HEC-1, Hydrologic, User Environment, Model Execution, Limitations, Analysis Features, Forecasting

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The current methodologies of the HEC-1 Flood Hydrograph Package are presented. The HEC-1 model provides a wide range of hydrologic capabilities along with several unique analysis features. The current limitations of the model are reviewed. Presently, much work is being done to overcome several of these limitations. Near-term developments have concentrated on making the operational environment user friendly and improving several of the hydrologic analysis features. The direction of HEC's future watershed modeling efforts

is described. These efforts focus on improving the user environment and advancing the hydrologic analysis capabilities to maintain state-of-the-art technology.

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